[redacted]8689-68 25X1A
Copy 8 of 19

3 January 1968

MEMORANDUM FOR DISTRIBUTION

SUBJECT: DD/S&T Career Development Course

1. The OSA portion of the Career Development Course will start on Wednesday, 28 February 1968. Sessions will probably be held in the [redacted]

25X1A

2. The projected schedule is given in Attachment I. Please advise [redacted] of any errors or changes.

25X1A

3. Each presenting officer is requested to prepare a course outline in the general format of Attachment II. Such course outline should be submitted to [redacted] on or before Friday, 18 January 1968. 25X1A

4. The class enrollment is furnished in Attachment III for your information.

[redacted] 25X1A

Assistant for Technology
Deputy for
Research and Development
Special Activities

Attachments:
I - Schedule
II - General Format
III - Enrollment

HANDLE VIA [redacted] 25X1A
CONTROL SYSTEM

25X1A A(T)D/R&D/OSA/[redacted](3 Jan 68)
Distribution:
Copy 1 - A(T)D/R&D/OSA
2 - D/SA
3 - EXO/SA
4 - COMPT/OSA
5 - D/R&D/OSA
25X1A 6 - ASD/R&D/OSA [redacted]
7 - PSD/R&D/OSA
25X1A 8 - ASD/R&D/OSA [redacted]
9 - SSD/R&D/OSA
25X1A 10 - SS/OSA [redacted]
11 - D/O/OSA
12 - OXC/O/OSA
13 - OXC/O/OSA
14 - OXC/O/OSA (
15 - IDEA/O/OSA
25X1A 16 - COMMO/O/OSA [redacted]
25X1A 17 - D/M/OSA [redacted]
25X1A 18 - [redacted]
19 - RB/OSA

SECRET

Attachment I
to [redacted]689-68 25X1A

OSA COURSE SCHEDULE, CDC #2

WEDNESDAY, 28 FEBRUARY

0900	INTRODUCTION	General Bacalis	
0945	OSA ORGANIZATION	[redacted]	25X1A
1045	BREAK		
1100	INTERFACE WITH OTHER OFFICES	[redacted]	25X1A
1200	LUNCH		
1330	GENERAL BRIEFING ON OXCART AND IDEALIST PROGRAMS	OPS	
1630	DISMISSAL		

25X1A

THURSDAY, 29 FEBRUARY

0900	ESTABLISHMENT OF SYSTEMS REQUIREMENTS AND DEVELOPMENT OF NEW SYSTEMS	[redacted]	
1100	PROJECT SECURITY (CONTRACTOR AND OPERATIONS)	[redacted]	25X1A
1200	DISMISSAL		

FRIDAY, 1 MARCH

0900	HISTORICAL REVIEW OF OSA AND PROJECTS	[redacted]	25X1A
1045	BREAK		
1100	R&D: ENGINE PERFORMANCE	[redacted]	25X1A
1200	LUNCH		

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HANDLE VIA [redacted] CONTROL SYSTEM 25X1A

FRIDAY, 1 MARCH (Continued)

1330	R&D: ENGINE PERFORMANCE, CONT	[redacted]	25X1A
1430	BREAK		
1445	R&D: VEHICLE PERFORMANCE, STRUCTURES	[redacted]	25X1A
1630	DISMISSAL		

MONDAY, 4 MARCH

0900	ENGINE/AIRCRAFT INTERFACE	[redacted]	25X1A
1015	BREAK		
1030	FLIGHT CONTROLS AND NAVIGATION	[redacted]	25X1A
1200	LUNCH		
1330	LIFE SUPPORT SYSTEMS	[redacted]	25X1A
1630	DISMISSAL		

TUESDAY, 5 MARCH

0900	SENSOR SYSTEMS	[redacted]	25X1A
1200	LUNCH		
1330	R&D: PROJECT MANAGEMENT	[redacted]	25X1A
1430	SYSTEMS TEST AND VALIDATION	OPS	
1530	DISMISSAL		

WEDNESDAY, 6 MARCH

0900	CONFIGURATION MANAGEMENT AND CONTROL	OPS	
1045	BREAK		
1100	COMMUNICATIONS	[redacted]	25X1A
1200	LUNCH		

WEDNESDAY, 6 MARCH (Continued)

1330	INTRODUCTION TO OPERATIONS	OPS
1430	DISMISSAL	

THURSDAY, 7 MARCH

0900	OPERATIONS, IDEALIST	IDEALIST OPS
1015	BREAK	
1030	OPERATIONS, OXCART	OXCART OPS
1200	LUNCH	
1330	MATERIEL, LOGISTICS, AVIONICS	[redacted] 25X1A
1630	DISMISSAL	

FRIDAY, 8 MARCH

1330	EXAMINATION	[redacted] 25X1A
1430	DISCUSSION SESSION	Mr. Duckett [redacted] 25X1A Col. Shelton [redacted] 25X1A
1630	DISMISSAL	

Attachment II to
[redacted]-8689-68 25X1A

EXAMPLE

LESSON TITLE: APPLICATION OF ADP IN OPERATIONS

DIVISION : AUTOMATIC DATA PROCESSING DIVISION/OSA

25X1A INSTRUCTOR : [redacted]

DATE/TIME/ PLACE : APRIL 4, 1967/1500-1600/

PART I - OVERVIEW

1. LESSON OBJECTIVE: The objective of this lesson is for each student to become familiar with the purpose and scope of the data processing efforts in pre-mission, mission, and post-mission operations.

2. INSTRUCTIONAL AIDS: Charts, Slides

3. TIME REQUIRED: 60 Minutes

4. PLAN OF PRESENTATION: The instructor will introduce the lesson by a brief history of the ADP Division, its purpose, organizational structure, equipment, and interface with the Office of Computer Services. Three major areas will be discussed: flight planning, vulnerability studies, and 1004 communication net. The accomplishments to date will be discussed by describing the programs generated in support of OXCART and IDEALIST operations. The UNIVAC 1004 data communications network will be discussed giving specific reference to the equipment and its principles of operation. Miscellaneous activities in support of operations will be outlined so as to present a full picture of automation usage in operations.

PART II - TEACHING GUIDE

A. INTRODUCTION

1. Division's Purpose and History
2. Organization Structure
3. Hardware and Software Systems

EXAMPLE

25X1 [redacted]

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HANDLE VIA [redacted] CONTROL SYSTEM 25X1A

EXAMPLE

B. FLIGHT PLANNING

1. OXCART

25X1A
(a) [redacted]
(b)
(c) Mission Planning Aids

2. IDEALIST
Project [redacted] 25X1A

C. VULNERABILITY STUDIES

1. OXCART
[redacted] Program 25X1A

2. IDEALIST
Project [redacted] 25X1A

D. UNIVAC 1004 DATA COMMUNICATIONS NETWORK

1. Equipment Description
2. Principles of Operation
3. Remote Site Locations

E. MISCELLANEOUS ACTIVITIES

1. Operation Plan Generation
2. Info Retrieval
3. Map Plotting
4. INS Readout
5. Camera Programs
6. Report Generation
7. [redacted] 25X1D

EXAMPLE

25X1A

EXAMPLE

List of Training Aids

Briefing Boards

1. Type A and B turn for A-12
2. Flight Conditions
3. UNIVAC 1004 Data Link Equipment

Slide

UNIVAC 1004 Equipment

EXAMPLE

HANDLE VIA [redacted]
CONTROL SYSTEM

25X1A

EXAMPLE

Test Questions

1. List five benefits derived by the use of computers in flight planning.

2. List three reasons why a non-engineering model was chosen for theprogramming of the A-12 program.

3. List five major areas of concern in the Project [redacted] program. 25X1A

4. Briefly describe the pitfalls of a vulnerability model.

5. List five major benefits of the UNIVAC 1004 as a communication terminal unit.

EXAMPLE

25X1A

Next 1 Page(s) In Document Exempt

25X1A

HANDLE VIA [redacted]
CONTROL SYSTEM

[redacted]-2242-67 25X1A
Copy 9 of 31

Office of Special Activities

The Financial and Technical Management of System Development

SCHEDULE

Monday - 3 April

25X1A

0900	6F25	Welcoming Remarks	General Bacalis D/SA
0915	6F25	Intent, Scope and Content of Course	[redacted]
0945	6F25	OSA Current Organization	
1030	6F25	Historical Development of the OSA Organization	
1230		LUNCH	
1330	2E62	The Intelligence Collection Superstructure	[redacted] 25X1A AD/DCI/NIPE 25X1A
1530	2E62	Working Relations with other offices	[redacted]
1630		CLOSE	

Tuesday - 4 April

0900	6B12	The establishment and revision of system requirements.	[redacted] 25X1A SA/DD/S&T (COMOR)
1000	6B12	Project Briefing	[redacted] 25X1A
1200		LUNCH	
1300	6B12	Project Briefing	[redacted]
1500	6B12	Application of ADP in Operations	
1600		CLOSE	

25X1A

ILLEGIB

Revised 27 March 67
HANDLE VIA [redacted]
CONTROL SYSTEM

[redacted]

OSA Schedule, Continued

25X1A

Friday - 7 April

0900	1E78	Air Force Systems Management Program	[redacted] AFSC, on film) 25X1A
1200		LUNCH	
1300	6F25	Review and Examination	[redacted] (with representatives of all offices involved to date)
1600		CLOSE	

25X1A

Monday - 10 April

0900	~~GA-13~~ 6F25	Materiel and Logistics	[redacted] 25X1A
1200		LUNCH	
1300	GA-13	OSA Security in Program Development	[redacted]
1430	GA-13	Communications in Development and Operations	[redacted]
1600		CLOSE	25X1A

25X1A

Tuesday - 11 April

0900	GA-13	Aircraft Performance Analysis	[redacted]
1030	GA-13	Engine Performance and Development	
1200		LUNCH	
1300	GA-13	The Aircraft-Engine Interface	
1345	GA-13	Flight Controls, Navigation, and Auxiliary Systems	
1515	GA-13	Sensor Development and User Interfaces	
1700		CLOSE	

25X1A

Revised 27 March 67

25X1A

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SAMPLE PRESENTATION

FOR AMS/OSA

AERO MEDICAL STAFF (AMS)

OFFICE OF SPECIAL ACTIVITIES

I. MISSION STATEMENT

AMS/OSA is responsible to the Director, Special Activities for the aeromedical aspects of OSA, DDS&T operations, training, and research and development. The function of AMS is to insure that the operational aircrew member is properly evaluated and selected; that his health, both physical and mental, is maintained at peak effectiveness; and that his personal protective, survival, escape, and evasion equipment, and training are up-to-date and satisfactory in order that the aircrew member can participate effectively in attaining OSA mission objectives.

II. STAFF RESPONSIBILITIES

CHIEF, AERO MEDICAL STAFF
(C/AMS/OSA)

AERO MEDICAL SUPPORT
(AS/AMS/OSA)

DEPUTY CHIEF, AERO MEDICAL STAFF
(DC/AMS/OSA)

LIFE SUPPORT
(LS/AMS/OSA)

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Next 3 Page(s) In Document Exempt

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S E C R E T

Responsibility of Medical

1. Selection of Project Pilots

a. Because of singular mission, every effort is made to select best from every aspect. Physical requirements, motivation, dedication, maturity, emotional stability, intelligence, adaptability, coordination, ability to get along with others, handle alcohol, etc.

b. They receive astronaut's Physical Evaluation at School of Aviation Medicine (SAM), Brooks AFB, Texas.

c. They are given a psychiatric interview by the Office of Medical Services' (OMS) psychiatrist and two to two-and-half day assessment and evaluation by psychologists from the Psychological Services Staff, OMS.

d. Aeromedical evaluation is made by the Chief, AMS/OSA, the Surgeon General's Office, a USAF-cleared liaison flight surgeon, and the Squadron Flight Surgeon. 25X1A

[redacted]

f. It must be realized that the original [redacted] 25X1A candidates nominated are top-flight, highest quality, and highly qualified jet pilots.

g. The pilots are carefully monitored at all times by the Squadron Flight Surgeon and annually receive astronaut's examination at Lovelace Clinic, New Mexico.

2. All integrees receive a CIA physical initially. All key personnel also receive psychiatric interviews and psychological assessments. It has been noted that a key administrative officer can compromise a program as easily as a pilot.

3. Health and physical standards are maintained with all non-flying personnel receiving 18-month standby physical.

S E C R E T

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EXAMPLES OF INCREASED SAFETY AND RELIABILITY IN THE S1010 PPA

1. Normal/Emergency O_2 delivery to the pilot.
2. Pressure protection in the event of cabin pressure loss or ejection.
3. Thermal protection on bailout, water survival, and cold-climate survival.
4. Integrated parachute harness.
5. Dual O_2 regulator, controller, and hose as well as dual O_2 storage.
6. Integrated flotation garment.
7. Fire protection for crash landing and/or cockpit fires.
8. Head and body protection from impact, dragging, or buffeting in flight and after ejection.
9. Installation of automatically activated life preserver.
10. Incorporation of 6-line release modification to personnel parachute.

SECRET
[redacted]

25X1

IDEA-0007-2-73
Copy___of___

23 February 1973

LESSON TITLE : Aero Medical Programs

DIVISION : Aero Medical Staff/OSA

INSTRUCTORS : [redacted] 25X1A

DATE TIME PLACE : 3 April 1973/1330-1600 - Control Center [redacted] Building 25X1A

PART II - OVERVIEW

1. LESSON OBJECTIVE: The objective of this lesson is for each student to become familiar with programs of the Aero Medical Staff/OSA. Specifically, the student will become familiar with the general physiological requirements for life-support equipment, the life-support system developed for and used in Project IDEALIST, and the Survival, Evasion, Resistance, and Escape (SERE) Training Program for project pilots.

2. INSTRUCTIONAL AIDS: Vu-Graph Slides and overhead projector, 35 mm Slides and Projector, and 16 mm Movie and Projector.

3. TIME REQUIRED: 2 hours 30 minutes

25X1

CLASSIFIED BY [redacted]
EXEMPT FROM GENERAL DECLASSIFICATION
SCHEDULE OF E. O. 11652, EXEMPTION CATEGORY
§ 5B(1), (2), (3) or (4) (circle one or more)
AUTOMATICALLY DECLASSIFIED ON
IMPDET
(unless impossible, insert date or event)

25X1

[redacted]
SECRET

4. PLAN OF PRESENTATION: The instructor will introduce the lesson by describing the overall organization and function of the Aero Medical Staff. Life-Support Programs will be discussed in Detail by describing the physiological requirements for life-support equipment, i. e., total barometric pressures, altered partial pressures, thermal balance, and protection during emergency ejections. In order to correlate physiological requirements with equipment in use, the life-support system as used in the U-2R will be discussed in detail. Finally, an overview of the [redacted] 25X1 Training Program and related specialized equipment will be presented:

PART II - TEACHING GUIDE

A. INTRODUCTION

1. Aero Medical Staff:

a. Organization and Function

b. Aircrew Selection

c. Maintenance

d. Resistance to Interrogation (RTI)

2. Life-Support Program Overview:

   Equipment types and categories

   a. Aircraft Systems

   b. Aircrew Systems

   c. Training

B. Physiological Requirements for Life-Support Equipment

1. Total Barometric Pressure

   a. Mechanical Effects of Pressure Change

      (1) Areas affected

      (2) Prevention/Protection

2. Altered Partial Pressures

   a. Decompression sickness

      (1) Areas affected

      (2) Protection/Prevention

   b. Boiling of Body Fluids

      (1) Areas affected

      (2) Protection

   c. Hypoxia

      (1) Cause and Effects

      (2) Protection

3. Thermal Balance

   a. Protection

25X1

a. Protection (cont'd)

(1) From heat

(2) From cold

4. Escape Provisions

a. Hazards

(1) Decision

(2) Decompression

(3) Separation

(4) Windblast

(5) Deceleration

(6) Spin

(7) Hypoxia

(8) Frostbite

(9) Parachute Opening Shock

(10) Parachute Landing and Canopy Release

(11) Survival

C. DESCRIPTION OF U-2R LIFE-SUPPORT EQUIPMENT

1. Oxygen System

2. Emergency Oxygen System

3. Ejection System

4. Pilot's Protective Assembly (PPA)

5. Improvements

25X1

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CONTENTS

I. A REVIEW OF HIGH ALTITUDE PHYSIOLOGY

A. Man and Oxygen

The fact that man requires a sufficient quantity of oxygen in order to metabolize nutrients and therefore produce energy is well known by all pilots of high performance/high altitude aircraft. After all, they have had one form of oxygen equipment or another strapped to their face, surrounding their head or entire body, while winking, blinking, and wheezing at them, almost since the first day they strapped a military aircraft on and penetrated the wild blue yonder. The following discussion will simply review the exact requirement for oxygen and the advantages of various types of oxygen delivery systems.

1. The Normal Oxygen Environment

a. Atmospheric Oxygen

Since men (at least the majority) have lived on earth they have been exposed to near sea level environmental conditions and are therefore physiologically adapted to such conditions. The sea level environment has a normal barometric pressure of 760 mmHg and a normal atmospheric composition of 20.99% Oxygen, 78.03% Nitrogen, with water vapor and other gases making up the remaining fraction (See Table 1). While pressure decreases with increasing altitude above sea level, the percent composition of the atmosphere remains constant (with respect to all gases except water vapor) to an altitude of at least 60 miles. At sea level, man is exposed to an oxygen environment which exerts a pressure of 160 mmHg (also called the partial pressure of oxygen and abbreviated as PO_2).

b. OXYGEN In Man's Lungs at Sea Level

The composition of air in man's lungs differs from the composition of the external environment for various reasons. Man's body contains a high percentage of water and his body temperature is constant, hence the water vapor pressure in his lungs will be constant at 47 mmHg. Normal ventilation of a healthy man's lungs is geared to maintain a constant Carbon Dioxide (CO_2)

Table 12. Effect of the Use of the Adjustable Press-to-Test Button on the pressure altitude within the S-1010 PPA

Aircraft Altitude (feet)	Barometric Pressure (psi)	Total Cabin (1) Pressure (psi)	Cabin (2) Altitude (feet)	Pressure Altitude in S-1010 PPA if manually inflated to indicated pressure: 1.0 psi	2.0 psi	3.0 psi	3.47 psi
50,000	1.69	5.57	24,500	20,500	17,250	14,250	13,000
55,000	1.33	5.21	26,000	22,000	18,500	15,250	14,000
60,000	1.05	4.93	27,500	23,000	19,500	16,000	14,750
65,000	0.83	4.71	28,500	24,000	20,250	16,750	15,500
70,000	0.65	4.53	29,000	24,750	20,750	17,500	15,750
75,000	0.51	4.39	30,000	25,250	21,500	18,000	16,250
80,000	0.41	4.29	30,500	25,750	21,750	18,250	16,750
100,000	0.16	4.04	31,500	26,750	22,500	19,000	17,500

(1) Constant $\triangle P$ = 3.88 psi
(2) Closest 500 feet

pressure within his body throughout a wide range of physical activity (from complete rest to maximum physical exertion). This normal PCO_2 is 40 mmHg. Table 2 presents the composition and partial pressure of gases within man's lungs at sea level.

c. Oxygen in Man's Lungs at 10,000 Feet

All pilots also know that a normal, healthy man can function well at 10,000 feet above sea level as long as the physical activity is limited. That is, he can fly his aircraft at 10,000 feet without supplemental oxygen, but above 10,000 feet he must utilize some form of oxygen equipment. Hence the oxygen pressure at 10,000 feet represents the minimum tolerable level and the oxygen pressure at sea level represents the optimum level. Therefore, oxygen pressures between these two values (ie 60 to 100 mmHg) can be considered normal for a pilot engaged in flying his aircraft. The values for 10,000 feet are given in Table 3.

2. The Oxygen Environment Above 10,000 Feet

a. Breathing Air

As barometric pressure is reduced with increasing altitude, so is the oxygen pressure within man's lungs. His body will attempt to compensate for this reduction by increasing ventilation to blow off CO_2 and thus make more "room" for oxygen. However, the effectiveness of this compensation is minimal since lowered CO_2 causes constriction of the blood vessels supplying the brain, therefore adding to the effect of oxygen deficiency on the central nervous system. At oxygen pressures less than 60 mmHg, the degree of impairment to a pilot is generally expressed in terms of Time of Useful Consciousness (T.U.C.). The T.U.C. for a given altitude (or PO_2) represents the average exposure time before a pilot engaged in minimal physical activity is no longer able to perform effectively (ie make correct decisions, control his aircraft, etc.). T.U.C. for a given individual can vary markedly from day to day depending on many factors. Table 4 presents the oxygen and T.U.C. situation for various altitudes above 10,000 feet.

b. Breathing Supplemental Oxygen

The basis for using some type of oxygen equipment for flight above 10,000 feet is that the reduction in barometric pressure can be offset by increasing the percentage of oxygen in the inspired air. The goal is to maintain a PO_2 in the lungs which is close to that found at sea level. It is obvious that once an altitude is reached where 100% oxygen is required to maintain a normal PO_2 in the lungs, additional efforts are required to ascend beyond this point. Pressure breathing (ie supplying 100% oxygen to the mask/lungs under a pressure over and above ambient pressure) extends mans altitude ceiling slightly, but has definite limitations. Two adverse effects which limit the effectiveness of pressure breathing are: (1) the possibility of lung damage, and (2) impairment of circulation. Lung damage can be produced if oxygen is supplied to the lungs at pressures greater than about 50 mmHg above ambient (ie above the pressure on the rest of the body). Impairment of blood circulation occurs, with increasing severity, as the pressure in the lungs is increased to any degree above ambient. Table 5 presents the PO_2 and T.U.C. situation for various altitudes above 10,000 feet for a pilot using ordinary diluter demand oxygen equipment. Table 6 presents the situation for pressure breathing above 40,000 feet.

c. Using a Pressure Suit

The only method by which sufficient oxygen pressure can be safely applied to man's lungs to allow him to fly at altitudes in excess of 45,000 feet, is to apply an equal counterpressure to the outside of his body. One method is to apply equal counterpressure only to the torso of the body, but this does not eliminate the problem of circulatory impairment and therefore only raises man's altitude ceiling slightly. A pressure suit therefore is a device which applies a pressure over the entire body that is equal to the oxygen pressure being applied to the lungs. This can be done by applying a mechanical pressure ("squeezing" action) over the body's surface as is done in, what have come to be called, "partial pressure suits." Various methods of squeezing the body for counterpressure have been developed over the years, but the most widely accepted and used garment is the U.S. Air Force developed "Capstan/Torso Bladder" partial pressure suit. The torso bladder is inflated to the same pressure as delivered to the oxygen inflated helmet, and is connected to the helmet so that slight changes in pressure during the breathing cycle are compensated for automatically. The capstans are elongated bladders which, when inflated, are one fifth the diameter of the individuals limbs and which apply equal counterpressure by tightening the inelastic material of the pressure suit over the extremities. Capstans over the torso region tighten the suit material to prevent the torso bladder from ballooning excessively, and therefore aid in mobility of the pilot. A full pressure suit is a pneumatic pressure suit that can be visualized as a man-shaped, form-fitting pressurized cabin. When inflated to balance the required oxygen pressure in the lungs, the full pressure suit expands away from, rather than squeezing, the body. Because the oxygen pressure delivered to the lungs is balanced by gas pressure instead of mechanical pressure, comfort in the inflated full pressure suit is greatly improved over the partial pressure suit. Table 7 compares the protection provided by the two types of pressure suits, revealing that the full pressure suit provides the pilot with a 35,000 ft equivalent altitude and the partial pressure suit provides a 40,000 ft equivalent altitude. One other feature of all pressure suits is that 100% oxygen is breathed at all altitudes. While this provides a higher PO_2 than required at altitudes under 35,000 feet, it provides for elimination of Nitrogen from the body which will be discussed in a later section.

d. A Word on Cabin Pressurization

The previous discussions of the effects of breathing air or supplemental oxygen, and the use of pressure breathing or pressure suits at various altitudes assumed that the pilot was exposed to the same ambient altitude at which his aircraft was operating. In actuality these conditions represent an emergency condition or at least an abnormal state since all modern aircraft utilize cabin pressurization as the primary system for providing physiological protection. In some aircraft, which can tolerate a large pressure differential and therefore maintain a low cabin altitude, oxygen equipment is used only as a backup or emergency system in the event of loss of cabin pressure. In other types of aircraft, cabin pressure and supplemental oxygen are used in combination to provide protection. In the aircraft of concern here the later case exists. Under normal operating conditions the pressure suit is merely providing supplemental oxygen (100% as previously noted) at cabin altitudes which exceed 10,000 feet and may reach 30,000 feet. With failure of the pressurization system to maintain at least 35,000 feet cabin altitude, the S-1010 PPA will take over the complete role of providing protection. Figure 1 presents the cabin pressurization schedule which will be used in combination with the S-1010 Pilots Protective Assembly.

B. Man and Nitrogen

While free gaseous nitrogen is said to be physiologically inert, it can have serious indirect effects when man is exposed to changing barometric pressures. The disorder related to nitrogen is called Decompression Sickness, which includes a wide variety of symptoms that may occur during or following a decompression (ie during or following a change from a high to a low pressure environment).

1. Nitrogen in the Body. Gaseous nitrogen is very soluble in man's body (about 5 times more soluble in fat than in water) and, as long as he remains at sea level, the quantities and tension (pressure) of nitrogen in his body remain constant. The absolute quantity of dissolved nitrogen depends on the size of the individual and the amount of fat in his body. The tension of dissolved nitrogen at sea level for all men breathing air will be identical since the dissolved tension will equal the PN_2 in the lungs. Therefore the nitrogen tension in the body of a man who has been residing at sea level for a finite period of time is 573 mmHg (See Table 2). The dissolved nitrogen in the body can be eliminated or reduced in either of two ways: (1) by reducing the level of or by eliminating Nitrogen in the gas mixture being breathed, or (2) by breathing air at a reduced total pressure, ie, at altitudes above sea level. In the first case either 100% oxygen, a mixture with less than 78% nitrogen, or a mixture containing normal oxygen but with the nitrogen replaced by another inert gas (Helium, Argon, Neon, etc.) will accomplish the reduction or elimination of nitrogen. In considering the flying business only, the only practical approach to reducing or eliminating Nitrogen from the body is the breathing of 100% oxygen before ascent to altitude. This approach will be discussed in detail in a later paragraph.

2. Decompression Sickness - Cause. While the disorder called decompression sickness (or caisson disease, bends, compressed air illness, evolved gas dysbarism) has been recognized for over 100 years, the exact physiological mechanisms giving rise to the various forms of the disorder are still not definitely known. However, the basic cause of all forms of decompression sickness is attributed to the formation of gaseous bubbles in the body during or following reduction of barometric pressure on the body. The chief gas involved in bubble formation is Nitrogen. Nitrogen bubbles can

form in the body whenever the dissolved nitrogen tension (PN_2) exceeds the total barometric pressure (PB) on the body by a critical amount: While the exact value for the critical difference is not known (it may differ between individuals, or may differ depending on absolute values of PN_2 and P_B) the range of values which can give rise to altitude decompression sickness is pretty well pinned down. The critical value is actually expressed as a ratio of Dissolved PN_2 to total P_B (PN_2/P_B). The highest value tolerable without the formation of bubbles is felt to be a ratio of 2/1, and the lower limit for a ratio which may give rise to bubbles is probably 1.5/1. In summary then, decompression sickness can occur whenever bubbles of Nitrogen are formed in the body during or following reduction of ambient pressure. Further, nitrogen bubbles can be formed whenever the dissolved Nitrogen tension in the body exceeds the total barometric pressure on the body by a factor of 1.5 to 2.0.

3. Decompression Sickness -- Effects. The signs and symptoms of this disorder are generally classified into 4 or 5 groups as follows:

   a. Skin Manifestations. Isolated areas of the skin may itch or give rise to a hot, burning sensation. An affected area may display a mottled, raised or blotchy appearance. While these symptoms are minor in themselves, they are sometimes seen in conjunction (preceeding or simultaneously) with more serious symptoms.

   b. Bends. The most common symptoms of decompression sickness are pains in or near one or more of the body joints. The pain is generally deep and aching, becomes progressively more severe, is aggrevated by exercise of the affected area, and may become incapacitating.

   c. Chokes. This serious form of decompression sickness has substermal burning, restricted breathing (due to pain), and a hacking cough as symptoms. In very serious cases, cyanosis (blueing of lips, fingernails) may appear. While these symptoms are generally seen in conjunction with others (bends, skin rashes etc), the chokes may occasionally be the only symptom experienced.

s. The most serious forms of decompression sickness involve either the circulatory system, the nervous system or both simultaneously. Symptoms may range from visual disturbances and headache through paralysis, delirium, shock, coma, and death.

4. Decompression Sickness - Treatment. For the pilot who encounters any form of decompression sickness in flight there is only one course of action--to increase the pressure on his body to reduce or eliminate the bubbles. This can be accomplished by descent, altering cabin pressure (if possible), or altering pressure within his pressure suit (if a suit is being worn). For the serious symptoms it is obvious that immediate descent to ground level is required. As an adjunct to the primary treatment (ie recompression) the pilot should remain on 100% oxygen all the way to ground level. Finally, even if symptoms are relieved in flight or upon return to ground level, the incident should be immediately made known to the flight surgeon because of the distinct possibility of a delayed reoccurrence or reaction.

5. Decompression Sickness - Prevention. In a previous paragraph it was stated that Nitrogen could be reduced or eliminated from the body by breathing 100% oxygen prior to ascent to altitude--a procedure called "Prebreathing" or "Denitrogenation." The rationale for this procedure is to reduce the dissolved Nitrogen tension to a level where the critical ratio of $PN_2/PB=1.5$ to 2.0 won't be encountered at the maximum altitude to which the pilot may be subsequently exposed. When a pilot breathes 100% oxygen at sea level, the nitrogen pressure (PN_2) in his lungs rapidly drops to zero. The blood flowing through the lungs contains a PN_2 of 573 mmHg and thus a pressure gradient of 573 to 0 exists and Nitrogen leaves the blood to be exhaled. This Nitrogen-free blood then passes through the body tissues and reabsorbs Nitrogen (tissue PN_2 is still 573 mmHg at this point) and again loses it on the next circuit through the lungs. As this process continues the pressure gradient from the blood to the lungs and from the tissues to the blood is decreasing exponentially, thus the rate of Nitrogen elimination drops off with time. The rate of Nitrogen elimination is also affected by two other factors: (1) different areas of the body contain different absolute quantities of Nitrogen dictated by the different amount of fat they contain, and (2) different areas of the body have different rates of blood flow, dictated by metabolic activity of the tissues involved. These two factors in combination

are most critical with regards to Nitrogen elimination and the potential for decompression sickness, since the critical ratio of PN_2/P_B, which relates to bubble formation, exists for <u>each</u> of the many types of tissues in the body. Therefore, while almost all Nitrogen can be eliminated in a short time from areas of the body with little fat and/or high rates of blood flow, areas with high fat content and/or low blood flows may retain a high PN_2 even after long periods of prebreathing. For determining nitrogen elimination the body is considered to have areas giving rise to 6 or more different nitrogen elimination rates, generally expressed as "half-times."

a. <u>Tissue Half-Times</u>. A tissue half-time is the time, in minutes, required for a tissue to lose one-half of its excess nitrogen content when exposed to a given gradient. Since bubble formation is dependent on Nitrogen pressure, the half-time of a tissue can also be expressed with respect to the PN_2 of a tissue. For purposes of determining prebreathing requirements the body is considered to have the following half-time tissues: 5, 10, 20, 40, 80, and 120 minutes. Table 8 displays the relationship between half-times, percent desaturation and PN_2. From this table it can be seen that only the slowest equilibrating tissue needs to be considered in the prevention of bubble formation by the process of denitrogenation. Hence the following prebreathing requirements are based on reducing the PN_2 of the 120 minute half-time tissue to a safe level with respect to the PN_2/P_B ratio.

b. <u>Critical PN_2 for Various Altitudes and Pre-Breathing Requirements</u>. By using the PN_2/P_B ratio and the PB for various altitudes, the critical PN_2 for the 120 minute (or any other) half-time tissue can be calculated. Then the prebreathing time required to reduce the PN_2 to or below this critical value can be obtained from the nitrogen elimination curve (or equation) for the 120 minute tissue. Table 9 presents the critical PN_2s and Figures 2a, 2b, and Table 10 present the prebreathing requirements for these altitudes.

TABLE 1

COMPOSITION OF THE ATMOSPHERE (DRY)

GASES :	N_2	O_2	ARGON	CO_2	H_2	Ne	He	Others
VOL % :	78.03	20.99	0.94	0.03	0.01	0.0012	0.0004	Traces
SEA LEVEL PARTIAL PRESSURE:	593 mmHg	160 mmHg	7mmHg (usually included with PN_2)					

TABLE 2

NORMAL COMPOSITION OF AIR WITHIN MAN'S LUNGS AT SEA LEVEL

	PRESSURE	VOL %
BAROMETRIC PRESSURE:	760 mmHg	100%
OXYGEN (PO_2):	100 mmHg	13.2%
NITROGEN (PN_2):	573 mmHg	75.3%
CARBON DIOXIDE(PCO_2):	40 mmHG	5.3%
WATER VAPOR (PH_2O):	47 mmHg	6.2%

TABLE 3

NORMAL PRESSURES OF RESPIRATORY GASES IN MAN'S LUNGS AT 10,000 FEET ABOVE SEA LEVEL

BAROMETRIC PRESSURE:	523 mmHg
PO_2 :	61 mmHg
PN_2 :	380 mmHg
PCO_2 :	35 mmHg*
PH_2O :	47 mmHg

*The reduction in PO_2 stimulates normal ventilation, thus reducing the PCO_2 slightly.

TABLE 4

EFFECT OF INCREASING ALTITUDE ON MAN BREATHING AMBIENT AIR

ALTITUDE (Ft above S.L.)	BAROMETRIC PRESSURE	RESPIRATORY GASES (mmHg)				T.U.C.
		PH_2O	PCO_2	PN_2	PO_2	
10,000	523 mmHg	47	35	380	61	Indefinite
18,000	380 mmHg	47	30	265	38	30 min
20,000	350 mmHg	47	30	239	34	10-15 min
25,000	282 mmHg	47	27	178	30	3-5 min
30,000	226 mmHg	47	27*	128	24	60-90 sec
35,000	180 mmHg	47	27*	87	19	30-60 sec
40,000	141 mmHg	47	27*	52	15	15-20 sec
50,000	87 mmHg	47	27*	4	9	9-12 sec
63,000	47 mmHg	47	0	0	0	9-12 sec

*Assumes PCO_2 does not fall below 27 mmHg. Measured values are unavailable at altitudes above 25,000 feet because the onset of hypoxia is so rapid.

TABLE 5

EFFECT OF SUPPLEMENTAL OXYGEN ON MAN AT ALTITUDES FROM 10,000 TO 63,000 FEET

ALTITUDE (Feet above S.L.)	BAROMETRIC PRESSURE (mmHg)	PERCENT OXYGEN INSPIRED	RESPIRATORY GASES (mmHg) PH_2O	PCO_2	PO_2	EQUIVALENT ALTITUDE *	T.U.C.
10,000	523	31	47	40	100	S.L.	Indefinite
13,000	380	42	47	40	100	S.L.	Indefinite
20,000	350	46	47	40	100	S.L.	Indefinite
25,000	282	57	47	40	100	S.L.	Indefinite
30,000	226	71	47	40	100	S.L.	Indefinite
35,000	180	100	47	40	93	S.L.	Indefinite
40,000	141	100	47	35	59	10,000	Indefinite
45,000	111	100	47	30	34	20,000	10-15 min
50,000	87	100	47	27	13	40,000	15 sec
63,000	47	100	47	0	0	63,000	9-12 sec

*Altitude breathing air that yields same PO_2.

TABLE 6

EFFECTS OF PRESSURE BREATHING ON MANS TOLERANCE TO HIGH ALTITUDES

ALTITUDE (Ft above S.L.)	BAROMETRIC PRESSURE	PERCENT INSPIRED OXYGEN	ADDITIONAL PRESSURE (1) REQUIRED	ADDITIONAL PRESSURE (2) DELIVERED	GASES (mmHg) PCO_2	PO_2	EQUIV ALT	T.U.C. (3)
35,000	180	100	0	3-5 mmHg*	40	100	S.L.	Indef
40,000	141	100	0-40	5-8 mmHg	35	64-67	10,000	Ind[illegible]
43,000	122	100	20-60	14 mmHg	35	54	12,000	Indef
45,000	111	100	30-70	20 mmHg	35	49	15,000	30 min
50,000	87	100	54-93	30 mmHg	30	34	20,000	3 min
63,000	47	100	94-133	30 mmHg	27	3	63,000	9-12 se

(1) Additional pressure required; range of pressures that would produce a PO_2 equivalent to that obtained breathing air at 10,000 feet to sea level.

(2) Additional pressure delivered: are actual pressure values delivered by standard pressure demand regulators. Are less than required because of adverse effects of higher pressures.

(3) T.U.C.: actual values may be less than shown due to circulatory impairment caused by pressure breathing having an additive effect to low PO_2.

*Slight pressure delivered at 35,000 is "safety pressure", used to overcome mask leakage.

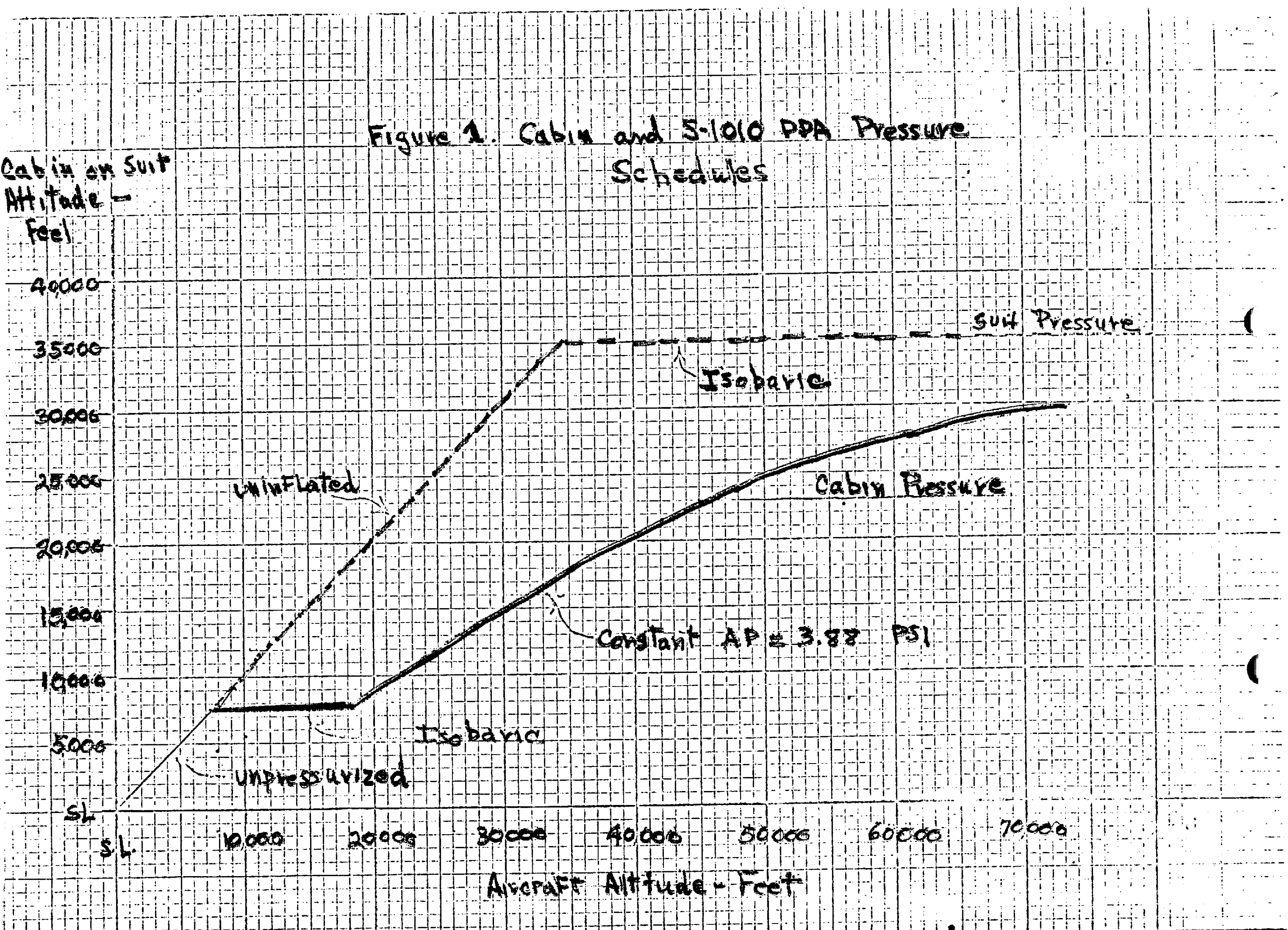

Figure 1. Cabin and S-1010 PPA Pressure Schedules

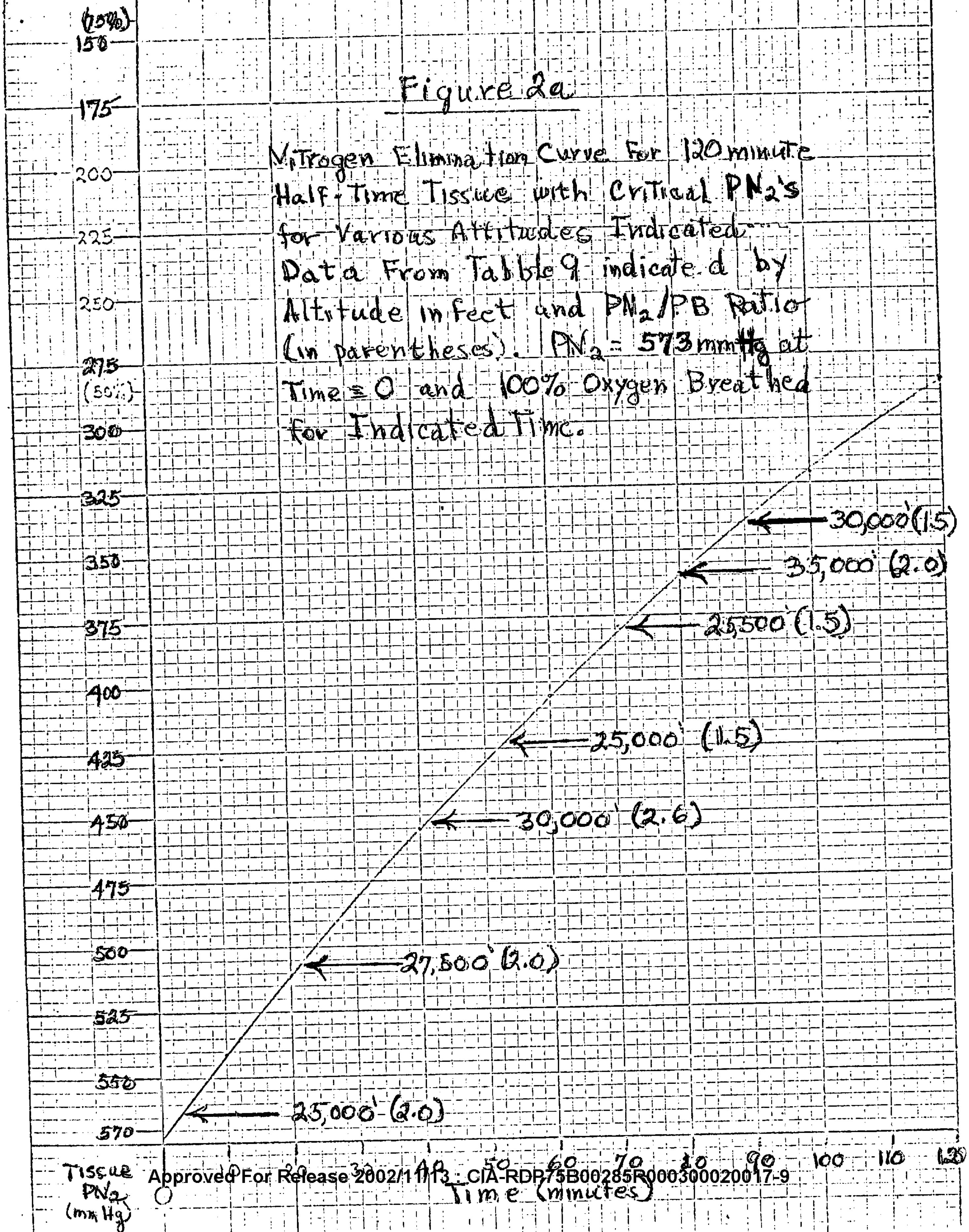

Figure 2a

Nitrogen Elimination Curve for 120 minute Half-Time Tissue with Critical PN_2's for Various Altitudes Indicated. Data From Table 9 indicated by Altitude in feet and PN_2/PB Ratio (in parentheses). PN_2 = 573 mmHg at Time = 0 and 100% Oxygen Breathed for Indicated Time.

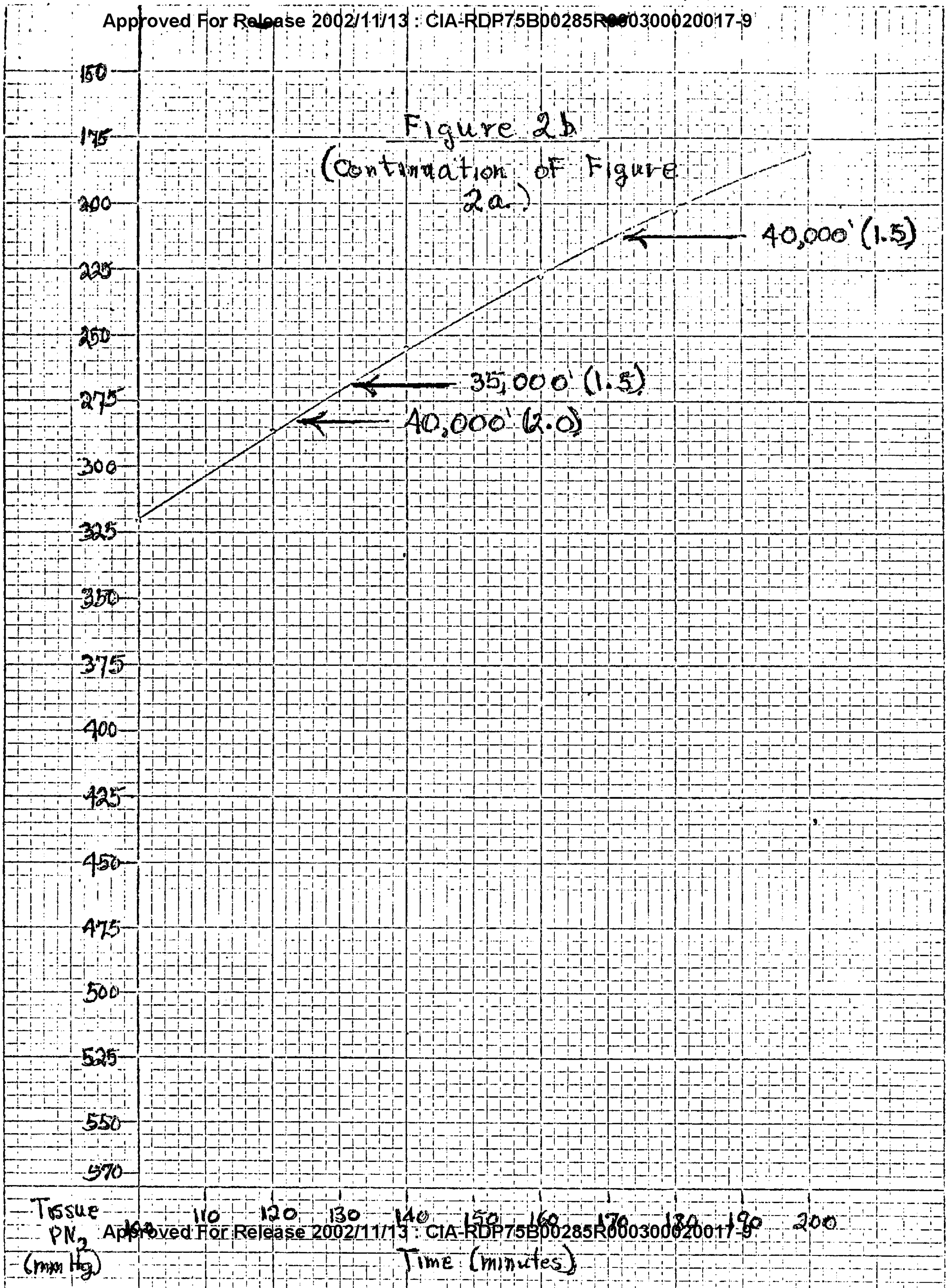

Figure 2b
(Continuation of Figure 2a.)

TABLE 7

A. Physiological Protection Provided by the Standard Capstan/Torso Bladder-type Partial Pressure Suit.

ALTITUDE Ft above S.L.	BAROMETRIC PRESSURE (mmHg)	(PSI)	BLADDER/ HELMET PRESSURE (mmHg)	PO_2 (mmHg)	EQUIV. OXYGEN ALTITUDE (1)	CAPSTAN PRESSURE (PSI)	BODY PRESSURE (PSI)	EQUIVALENT PRESSURE ALTITUDE (2)
40,000	141	2.73	4	63	10,000	0	2.73	40,000
50,000	87	1.69	55	60	10,000	5	2.69	40,000
63,000	47	.91	100	65	10,000	10	2.91	38,500
100,000	8	.16	145	60	10,000	14.5	2.95	38,500

(1) Equivalent oxygen altitude: altitude breathing air that yields same PO_2.

(2) Equivalent pressure altitude: Pressure altitude obtained by total of suit pressure plus ambient pressure.

B. Physiological Protection Provided by a Full Pressure Suit (3.5 PSI type).

ALTITUDE Ft above S.L.	BAROMETRIC PRESSURE mmHg	PSI	SUIT PRESSURE (gage) mmHg	PSI	PO_2 mmHg	EQUIV. OXYGEN ALTITUDE (1)	ABSOLUTE PRESSURE IN SUIT	EQUIVALENT PRESSURE ALTITUDE (2)
35,000	179	3.47	4	-	100	S.L.	3.47	35,000
40,000	141	2.73	38	0.74	100	S.L.	3.47	35,000
50,000	87	1.69	92	1.78	100	S.L.	3.47	35,000
63,000	47	0.91	132	2.56	100	S.L.	3.47	35,000
100,000	8	0.16	171	3.31	100	S.L.	3.47	35,000

TABLE 8

The relationship between Percent Nitrogen Desaturation, PN_2 and Time for Tissue Half-Times from 5 to 120 minutes. All tissues assumed to have 570 mmHg PN_2 (100% saturation) at T = 0, and maximum gradient applied at T = 0 (ie 100% oxygen breathed).

Time (T) in Minutes to Attain Given PN_2 and % Desaturation

PN_2 (mmHg) :		570	285	142.5	71.25	35.6	17.8	8.9
Desaturation (%) :		0	50	75	87.5	93.75	96.9	98.4
Tissue Half-Times (minutes)	5	0	5	10	15	20	25	30
	10	0	10	20	30	40	50	60
	20	0	20	40	60	80	100	120
	40	0	40	80	120	160	200	240
	80	0	80	160	240	320	400	480
	120	0	120	240	360	480	600	720

TABLE 9

Critical Tissue PN_2 for Various Exposure Altitudes and Critical PN_2/P_B Ratios of 2.0 and 1.5.

Exposure Altitude (Feet above S.L.)	Barometric Pressure (mmHg)	Critical Tissue PN_2 at Indicated Ratio	
		2.0	1.5
25,000	282	564 mmHg	423 mmHg
27,500	253	506	379.5
30,000	226	452	339
35,000	179	358	268.5
40,000	141	282	211.5

TABLE 10

Prebreathing Time required to reduce PN_2 of 120 minute tissue to critical level for various exposure altitudes, using PN_2/P_B = 2.0 and 1.5 ratios from Figures 2a and 2b.

Altitude (Feet above S.L.)	Time Breathing 100% Oxygen at S.L. To Reduce PN_2 to Critical Valve For PN_2/P_B Indicated	
	PN_2/P_B = 2.0	PN_2/P_B = 1.5
25,000	3 min	53 min
27,500	21 min	71 min
30,000	41 min	90 min
35,000	80 min	131 min
40,000	123 min	171 min

Table 11.

Suit Pressure Applied (psi)	Exposure altitude requiring this Pressure (feet)
0.5	38,000
1.0	42,000
1.5	47,000
2.0	53,000
2.5	62,000
3.0	77,000
3.47	Space